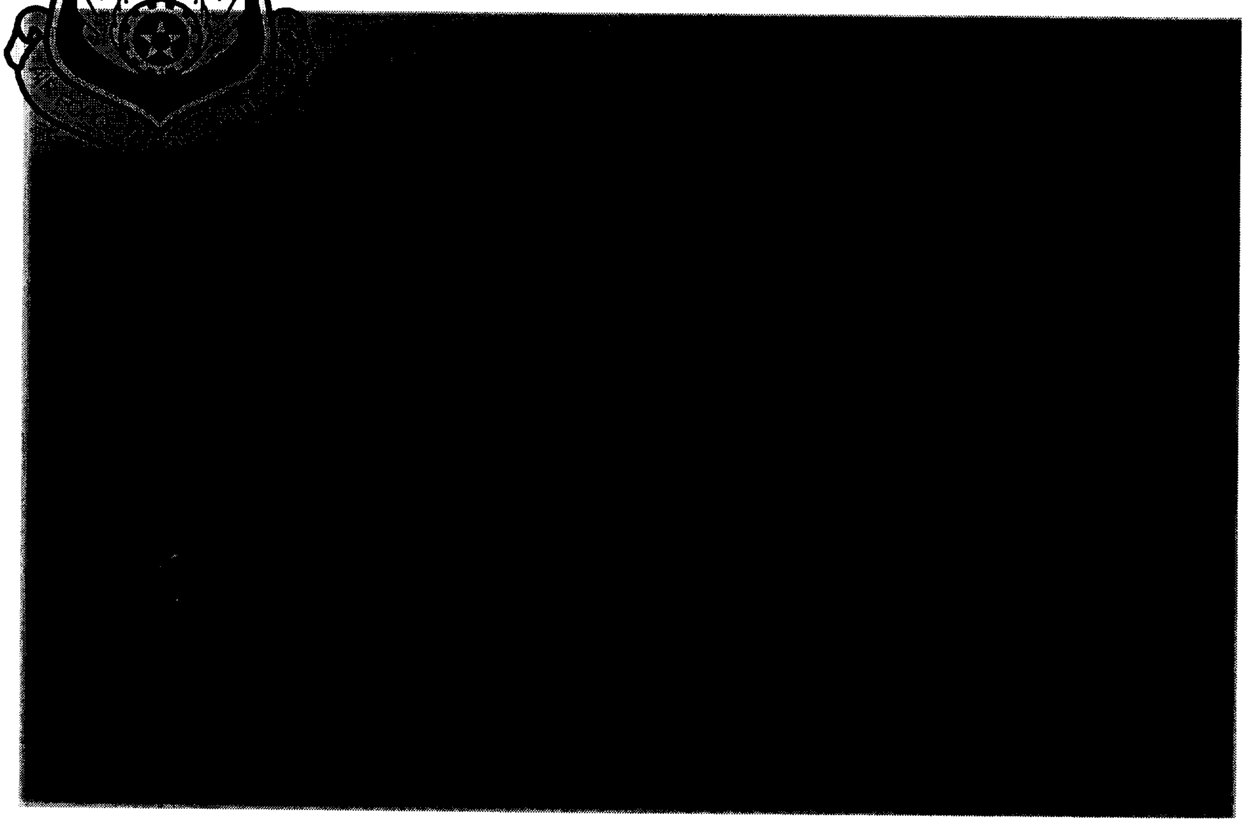
FY98
DIRECTED ENERGY TECHNOLOGY AREA PLAN



AIR FORCE RESEARCH LABORATORY

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Note: This Technology Area Plan (TAP) is a planning document for the FY98-03 S&T program and is based on the President's FY98 Budget Request. It does not reflect the impact of the FY98 Congressional appropriations and FY98-03 budget actions. You should consult PL/XP, DSN 246-4962 or Commercial (505) 846-4962 for specific impacts that the FY98 appropriations may have had with regard to the contents of this particular TAP. This document is current as of 1 June 1997.

DIRECTED ENERGY

VISIONS AND OPPORTUNITIES

The Phillips Laboratory (PL) develops and transitions warfighting technologies in three primary areas: space and missile systems, geophysics, and directed energy.

This Technology Area Plan encompasses the development, demonstration, and transition of Directed Energy technologies; the determination of the susceptibility of USAF systems to similar foreign threats; and the development of protection technology to enhance the survivability of USAF systems. On-going and planned R&D will lead to advanced weapon systems using high energy lasers, high power microwaves, and related capabilities such as high resolution optical imaging. Efforts in survivability assessment and protection technology involve the development of both hardening technology and the criteria for protecting USAF systems against directed energy weapons, and natural and enhanced space radiation.

As the national center of excellence for directed energy, PL is well qualified to provide the technology for tomorrow's warfighters. Directed energy weapons (DEWs) offer the opportunity to leapfrog over incremental advances in conventional weapons by providing revolutionary capabilities for both offense and defense. These technologies and the advanced weapon systems they make possible are a critical part of the Air Force's "Global Engagement" vision.

Within the Directed Energy Technology Area, PL develops moderate and high power laser devices; highly accurate optical acquisition, tracking, and pointing technology; high resolution optical imaging; moderate and high power Radio Frequency (RF) weapons and countermeasures; and protection technologies. These application technologies are supported by on-going research in pulse power, nonlinear optics, target effects and vulnerability, survivability assessments, and systems performance and mission effectiveness analysis.

After years of investment, laser devices have reached a maturity which supports a clearly defined path to operational systems for both weapon and supporting applications. A realistic example of a weapon system is airborne theater missile defense (TMD) roles. Lightweight, compact, and efficient lasers at moderate power and selected wavelengths also are envisioned for a variety of applications, such as imaging, infrared countermeasures (IRCM), communications, illumination, target designation, special operations and Nuclear

Biological and Chemical (NBC) detection.

The coming decade will see a demonstrated capability in beam control systems. Continued progress in compensating for beam distortions due to atmospheric turbulence will provide enabling technology for long-range laser weapon systems. The proven ability for high accuracy tracking and beam pointing give credibility to the precise application of energy at the speed of light to specific target aim points. With the combination of laser source and beam control technologies, the laser as a viable weapon system will come of age. We fully expect laser systems to proliferate in the Air Force inventory within the next ten years.

Maturing laser source and beam control technology is also the foundation for a revolution in optical imaging technology. Atmospheric compensation and illuminator laser technology, in combination with innovative image sensing and processing concepts, will greatly improve the coverage and resolution of imaging systems. Operational commands will obtain high quality, timely imaging products for applications such as space object identification, long range airborne imaging, and new technology approaches for space-based sensors. These technologies will become the eyes of the future Air Force.

Another promising capability in the coming decade will be the use of High Power Microwave (HPM) technology. HPM will represent a major potential advance in Electronic Warfare technology by extending conventional RF power output several orders of magnitude. This enables the damage and disruption of a broader range of targets and simplifies the threat-specific nature of systems. HPM will be used to attack multiple enemy communications and radar systems, and will be useful as a potential generic countermeasure to a wide range of IR and RF guided weapons. Several advanced technology demonstrations of HPM weapon concepts are planned in coordination with USAF operational users. This electronic sword works both ways, however, and protecting US electronic assets is equally important. This involves not only the careful design of US HPM weapons, but also hardening US assets against potential enemy HPM and other inadvertent RF threats. PL is at the forefront in developing RF susceptibility measurement and systems hardening technologies for transition to military users and industry. Finally, PL is pursuing advanced pulse power development as a key technology for high power RF sources.

Integral to S&T investment strategy and planning is the development of advanced technologies and tools that assure the operational capabilities and military utility of evolving systems supporting critical mission areas such as Space Control. As we transition from an Air Force to the Air and Space Force of the future, we must provide the technologies and capabilities that provide protection of our space systems from a broad spectrum of potential threats. The importance of protection and the associated element of satellite threat warning and attack reporting is receiving increasingly high levels of visibility as the space architectures of the future are being refined and the systems supporting those architectures are designed, developed, and made operational. PL embodies world-class experimental and computational tools to complete unique survivability and vulnerability assessments of US and foreign space systems, subjected to a wide range of threat environments. Over the next few years PL will continue to integrate the survivability and vulnerability characteristics of additional classes of space systems, with their mission-critical payloads, into modeling and simulation capabilities to predict threat-stressed performance in operational environments. This will lead to the determination of survivability enhancement options, and the development of protection technologies to mitigate performance degradation as a result of natural and enhanced radiation, optical and DEW threats, KEW, and other advanced terrestrial, airborne, and space-based weapons.

PL's vision in directed energy is one of providing major new military capabilities and shaping the nation's defense posture. Talented and dedicated PL professionals along with modern research facilities stand ready to meet the challenge of military superiority in the next century.

This plan has been reviewed by all Air Force laboratory commanders/directors and reflects integrated Air Force technology planning. I request Air Force Acquisition Executive approval of the plan.

MICHAEL L. HEIL, Colonel, USAF
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Major General, USAF
Technology Executive Officer

CONTENTS

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INTRODUCTION

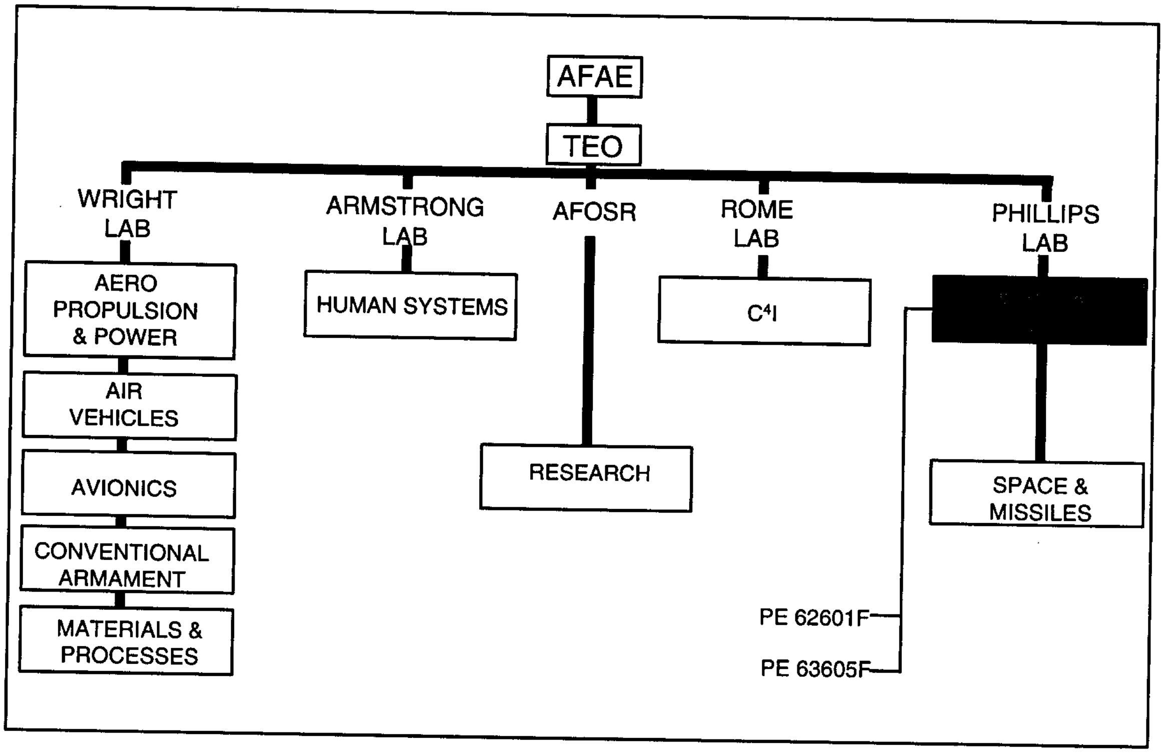


Figure 1. AF S&T Program Structure

BACKGROUND

The Directed Energy Technology Area is managed by the Commander of the Phillips Laboratory, as indicated in Figure 1. It is executed by the Advanced Weapons and Survivability and the Lasers and Imaging Directorates, with the majority of the technical activities performed at Kirtland AFB, New Mexico. This Technology Area encompasses the development, demonstration, and transition of directed energy and assessment of the survivability of USAF systems to similar foreign threats. For advanced weapon concepts, on-going and planned R&D will lead to high energy lasers, high power microwaves, high energy plasmas, and related capabilities such as high resolution optical imaging. Establishing the control and exploitation of space also requires the development of both hardening technology and the criteria for protecting USAF systems against directed energy weapons, nuclear weapons, and natural and enhanced space radiation.

Directed Energy is the one technology area where truly dramatic advances in warfighting capabilities will occur. The ultimate goal is new weapons development and transition, enabling the Air Force to leap over the on-going evolutionary development process for conventional weapons, and thereby provide superior

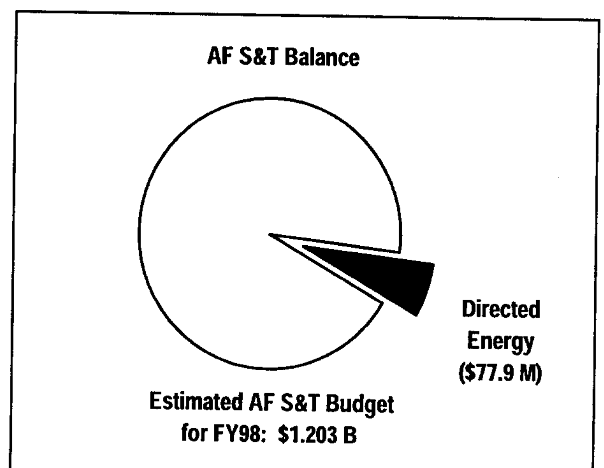


Figure 2. Directed Energy S&T Vs AF S&T

capabilities to support our national security.

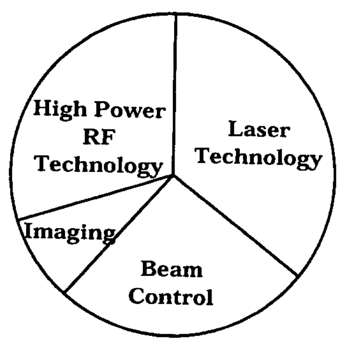
Figure 2 shows the estimated Air Force S&T budget for FY98 with the exploded segment showing those funds that are programmed for Directed Energy.

The Directed Energy Technology Area is

divided into the following four major Technology Thrusts:

1. LASER TECHNOLOGY
2. BEAM CONTROL
3. IMAGING
4. HIGH POWER RF TECHNOLOGY

The division of the Directed Energy Technology Area funding by major thrust is shown in Figure 3.



Estimated Directed Energy S&T Funding for FY98: $77.9M

Figure 3. Major Technology Thrusts

Thrust 1 Laser Technology: The Laser Technology Thrust provides innovative research and development in Chemical Laser Technologies, Semiconductor and Solid-State Laser Technologies, and Advanced Laser Concepts and Effects for military applications in weapons, communications, battlefield illumination, and InfraRed Countermeasures (IRCM).

The Chemical Laser Technologies subthrust consists of continuing efforts in Chemical Oxygen Iodine Laser (COIL) development and scaling. This includes the demonstration of advanced concepts for improved efficiency, lighter weight, higher pressure operation, and reduced construction and operating costs. These advances in COIL technology are applied to the ABL TMD and GBL missions through extended run times and higher power DEWs. Current work will examine the development of high average power frequency conversion, incorporation of an unstable resonator, and gain switching of the RADICL device.

The Semiconductor and Solid-State Laser Technology subthrust is divided into two major areas. First, the development and scaling of semiconductor laser diode and diode array technologies for military applications, including scaling individual laser diodes to higher power and better beam quality and the demonstration of architectures for coherent laser arrays. The second major area is the application of incoherent semiconductor laser diode arrays as efficient light sources to pump other solid-state lasers, with near-term development and fielding of moderate power lasers (1-10kW) for illuminator and countermeasure applications.

Applications of the two subthrusts include installation of an aerosol detection system and development of the Active Track Laser (ATLAS), a diode pumped Neodymium Yttrium Aluminum Garnet (Nd:YAG) laser. The ATLAS demonstrated near diffraction limited performance at an average output power of 750 watts. The output was frequency doubled to produce the highest power solid-state green laser ever reported. ATLAS will be used in the illumination and tracking of satellites.

The Advanced Laser Concepts and Effects subthrust covers the investigation of the following alternative missions: Lasers and Space Optical Systems (LASSOS); advanced laser concepts; laser effects; IRCM; fiber lasers; laser illuminators. The payoff is continuous wave, single frequency, polarized laser devices for military applications.

Innovative applications of the Advanced Laser Concepts and Effects subthrust include the Battlefield Optical Surveillance System (BOSS), pictured on page ii, just under the Directed Energy heading. BOSS is an integrated, self-contained, counter-sniper/counter-riot system mounted on a Highly Mobile Military Vehicle (HMMV). It uses both a visible green and infrared laser to maintain safe stand-off distances from an adversary while deterring hostile aggression.

Thrust 2 Beam Control: The Beam Control thrust involves the development and transition of advanced optical systems for laser propagation and high resolution imaging applications. This includes technologies for adaptive optics, highly-accurate target acquisition and tracking, precision beam pointing for aimpoint control, and high quality optical components. A major effort under this thrust is the development and demonstration of weapon-class beam control technology for both ground-based and airborne laser systems.

The Ground Based Laser (GBL) Technology subthrust is responsible for the demonstration of weapons class atmospheric compensation and acquisition, tracking, and pointing (ATP) technologies for GBL applications, through the development and low power testing of a full-scale, integrated GBL beam control system. In early FY97 a field test series called the Tilt Anisoplanatism Measurement Experiment (TAME) was performed at the Starfire Optical Range (SOR) 1.5 meter telescope.

The experiment used binary stars to demonstrate closed-loop, real-time compensation of tilt anisoplanatism, a degrading effect of atmospheric turbulence which is manifested as a track jitter error. Installation of the new adaptive optics system for the SOR 3.5 meter telescope is expected to be completed by summer FY97.

The Airborne Laser (ABL) beam control technology subthrust is responsible, with Geophysics, for the characterization of the high altitude, near horizontal propagation path environment and the evaluation of the performance requirements for the high bandwidth adaptive optics and active tracking technology in ABL systems for boost-phase Theater Missile Defense (TMD). During FY97, the second phase of a unique optical turbulence measurement over White Sands Missile Range (WSMR) was successfully executed. The atmospheric turbulence measurement, known as the Aircraft-Radar-Turbulence (ART) experiment, captured high altitude optical turbulence data from sensors mounted on the Phillips Laboratory's Argus airborne testbed and with the Army's WSMR atmospheric profiler radar.

The Optical Component Technology subthrust covers the development and characterization of specialized optical components and coatings for use in high energy laser (HEL) systems, with emphasis on low absorption, low scatter, high reliability, and environmental stability. Specialized optical components and fabrication techniques are developed to support the HEL systems required for the GBL and ABL TMD missions identified above.

Thrust 3 Imaging: The Imaging Thrust involves the development and transition of multiple spectral sensing and sensor data processing technologies for high resolution imaging and remote sensing applications. This thrust takes advantage of adaptive optics and target acquisition/tracking technologies developed under the Beam Control Thrust to produce a compensated, stabilized image which can then be further improved with advanced imaging sensors and post-processing of the image. Advanced concepts which can reconstruct images from interferometric or speckle data are also being pursued.

The high resolution imaging and remote sensing applications include space surveillance, space object identification, battlefield surveillance, and long range detection of nuclear, biological and chemical agents or aerosols. High resolution imaging includes the development and field demonstration for 24 hour coverage of low-earth orbit (LEO) satellites using passive imaging techniques and geosynchronous orbit (GEO) satellites using active imaging technologies. The long range detection and remote sensing technologies will help provide detection of warfare agents, battle damage assessment, and target identification.

The Active Imaging Testbed (AIT) has been designed and is being fabricated and integrated as a complete system at the SOR. The purpose of this effort is to demonstrate the capability and utility of coherent imaging techniques for high resolution imaging of LEO satellites. Experiments and modifications to the AIT will be conducted to evaluate imaging techniques that could be extended from LEO out to GEO.

The objective of the Passive Imaging Technology subthrust is to investigate, develop and demonstrate advanced imaging concepts for use in space-based applications. This subthrust consists of two technologies: 1) Smart, lightweight, space-based optical sensors and 2) Spectroradiometry for imaging targets on earth from space.

The Space Based Imaging program has continued to research technologies for building large, high resolution lightweight imaging systems for GEO. A meter-class laboratory breadboard for use in the characterization of nonlinear optical (NLO) and electro-optical (EO) wavefront correction has been constructed. Both correction techniques, EO and NLO, will be demonstrated by the end of FY98. Additionally, the Space Based Imaging Program has designed and is in the process of building a new membrane mirror for space. This meter-class membrane mirror can then be tested in the above laboratory breadboard.

The remote optical sensing subthrust includes chemical warfare agent detection and identification, counter-proliferation, intelligence preparation of the battlefield through effluent characterization, counter-drug, mobile target detection, underground facility characterization, and battle damage assessment. Specific technical initiatives include hyperspectral sensors in the thermal region and LIDAR systems for airborne and space platforms.

Thrust 4 High Power RF Technology: The goal of the High Power RF Technology thrust is to develop and transition HPM weapons technology into the AF operational inventory and to protect US systems against potential radio frequency (RF) weapons threats. Efforts include technology development and demonstrations of advanced HPM technologies, and development and

transition of RF hardening techniques to AF Product Centers and industry.

Major milestones have been attained in demonstrating high power RF sources for a variety of wide- and narrow-band weapon applications -

- Aircraft self protection (ASP)
- Suppression of enemy air defenses (SEAD)
- Command and control warfare (C^2W/IW)
- AF Space Control

A RF effects and hardening database is being built in concert with AF Information Warfare Center, and PL has developed an automated RF effects components and C^2W subsystem testing capability to support these efforts. A full-scale mock-up of an F-16, from the cockpit forward, has also been constructed to support avionics systems HPM effects testing.

Thrust four also assesses the vulnerability of foreign space systems in support of advanced weapon technology development programs, and defines the hostile space threat environments in which US systems will operate. The challenge is to determine the effects of high power microwaves on both foreign and US space systems and then to incorporate these findings along with the laser effects from Thrust 1 into models and computer codes which predict space systems endurability and sustainability.

RELATIONSHIP TO OTHER TECHNOLOGY PROGRAMS

The Directed Energy technology area interacts with several other technology areas through a wide range of relationships with other agencies. These relationships range from informal coordination between technical personnel to formal program management direction. Specific relationships are established through interchanges at technical meetings, seminars and symposia. If appropriate, they are formalized through Memoranda of Agreement (MOAs) or Memoranda of Understanding (MOUs) which delineate the responsibilities for supporting directed energy technologies.

The Directed Energy technology area benefits from support for basic research provided by the AFOSR Research technology area. Individual tasks investigate a range of new technology concepts within four major thrusts, with potentially high payoff for transition to longer-term development and scaling efforts. Examples include the investigation of novel, short wavelength laser concepts, adaptive optics phenomenology, basic physics issues for high performance optical coatings, aero-optics effects, advanced imaging concepts, high power RF sources, ultra high energy pulse power, and development of new parallel 3D codes for simulation of complex physics applications as well as performance of large-scale, three dimensional calculations.

There are many PL cooperative programs within the Air Force. In High Power RF Technology they include Wright Labs on IR missile countermeasures, Rome Labs on Information Warfare (IW), Armstrong Laboratory on Active Denial Technology, AFFTC & AEDC on RF test facilities for aircraft & satellites, and an Air Staff sponsored program on IW protection and hardening. The Materials Directorate, WL, is also pursuing development of high power optical component technology, which is directly relevant to the goals of the Beam Control thrust.

Among the Services, work in the directed energy area is coordinated through the Technology Sub-Panel for Directed Energy Weapons (TPDEW) of the Director of Defense for Research and Engineering's (DDR&E) Defense Technology Area Plan (DTAP). High Power RF Technology coordination has included transition of AF HPM sources to Army programs, leverage of RF effects tests on communications gear (MICOM) and missiles (MISIC & NRL) for AF programs, and cooperation on large aircraft RF effects tests and wide band source development at NSWC. The Federal Defense Laboratory Diversification Program is also the agent for transitioning RF effects developments to industry. There is an agreement among the services that the AF will support the development of adaptive optics technology for atmospheric compensation, with the resulting technology base available to the other services to support their applications.

There is also a significant degree of cooperative work with other government agencies and their laboratories. DOE laboratory representatives participate in TPDEW meetings to improve coordination and identify areas for cooperation. For example, cooperative or collaborative work exists with DOE laboratories on pulse power, compact HPM source development, RF effects tests, power beaming technology investigations, specialized security sensor development, RF coupling code development, and mid-IR semiconductor laser diode development. Power beaming and long range laser communications are being investigated with NASA, and RF threats to aircraft is being pursued with the FAA.

PL S&T investments are significantly enhanced by teammates in the industrial sector. There has been continuing emphasis on technologies oriented to airborne laser systems,

stimulated by the establishment of the ABL program. There also continues to be significant investment by industry in the area of high energy chemical lasers, advanced optical imaging, semiconductor laser diodes, HPM sources, and RF hardening. A close relationship with industry is also illustrated through a number of active Cooperative Research and Development Agreements (CRDAs) in areas such as laser development for materials processing and medical applications, optical coatings process development, HPM source development, and RF effects testing and hardening of commercial vehicles (GM), aircraft (Boeing), and computer components (Intel). Recently, an advanced metal detector system for detecting weapons carried by personnel was developed under a jointly funded effort between PL and private industry. This will revolutionize walk-through personnel security systems such as are located at airports.

PL manages the SMC Small Business Innovative Research (SBIR) program. In proposing topics for the SBIR program, one of the strong considerations has been the potential for commercialization of the potential product, as well as the innovation required for a solution. This concept maximizes the potential gain for both the small business and the government. There are five new SBIR Phase I efforts that have been awarded in April 1997. Three of the efforts address methods of extending the pulse duration of high power microwave (HPM) sources to improve output for both military and commercial applications. Another effort is developing ultra-wideband (UWB) waveguide bends to reduce or eliminate the losses in waveguide bends. This will allow UWB sources to be installed in aircraft and other configurations requiring complex waveguide routing. The other Phase I efforts address automatic identification of moving vehicles, optimization of wireless LANs using in-situ testing, and high power acoustics to provide security to facilities and control riots. Phase II SBIR efforts are developing a commercial version of the PL patented electronic mode stirred chamber to test electronic systems for EMC/EMI effects, development of a UWB antenna for installation on aircraft, and development of a network analyzer with integrated modulation capability to provide full characterization and testing of wireless communication systems. A successful Phase II effort has just been completed to develop a new class of instrumentation that allows simultaneous multiple distributed electromagnetic measurements that are time and frequency synchronized. This system is entering a Phase III commercialization phase with production and delivery of systems beginning in June 1997.

Interactions with international R&D programs are productive in essentially all areas of research within the Directed Energy Technology Area. The interaction ranges from the exchange of data and information in areas of common interest, through the funding support of specific research initiatives in foreign countries, to the joint support of specific research and testing initiatives both at home and abroad. A total of 10 different international agreements are involved, with an estimated dollar value exceeding $1 million.

The Atmospheric Characterization effort of the Beam Control thrust closely collaborates with Geophysics programs in the Space and Missiles Technology Area to characterize the environment that affects Directed Energy systems. The program includes measurements and modeling of atmospheric optical turbulence, including meteorological dependencies.

CHANGES FROM LAST YEAR

The Directed Energy Thrust 5, Space Control Technologies, has been eliminated and reorganized under Thrust 4, High Power RF Technology, Thrust 1, Laser Technology, and Thrust 3, Imaging. Thrust 4's title has been changed from RF Weapons to High Power RF Technology. Reduced funding has resulted in limiting RF Space Control research to efforts aimed at general effects & RF technology development. Laser effects work from thrust five has been incorporated into subthrust 1C, Advanced Laser Concepts and Effects. The Intelligence Data Analysis System for Spacecraft (IDASS) has been incorporated into Thrust 3, Imaging. Additionally, two Focused Technology Areas (FTAs), Nonlinear Optics (A1D01) and Imaging Applications (A3A06), have been eliminated with the work allocated to other FTAs. All space debris work has been transferred to the Space and Missiles Technology area. The balance of Thrust 5, Threat Warning and Attack Reporting , and Satellite Assessment efforts has been moved to Thrust 4, EM Effects & Hardening.

THRUST 1: LASER TECHNOLOGY

USER NEEDS

This thrust supports the following mission areas and associated technology needs or deficiencies as provided in the current Mission Area Plans (MAPs):

Air Force Space Command

1. Counterspace/Space Control: counter-space (negation).
2. Command & Control/Force Application: no current weapon systems - high energy lasers.
3. Command & Control: satellite communication crosslinks (laser).
4. Space Surveillance: limited space intelligence support (SOI, MPA, imagery, status assessment).

Air Combat Command

1. Theater Missile Defense: attack and kill capability - Airborne Laser (ABL).
2. Counter Air: laser infrared counter-measures (IRCM).

Air Force Special Operations Command

1. Joint Air-SOF Battlefield Interface: secure, antijam, low probability of intercept/low probability of detection (LPI/LPD) communications.
2. Combat Support: enhanced medical field laser system; security police directed energy weapon (DEW) capability; reliable, pocket-size, chemical detection device; chemical standoff detection system.
3. Force Application: future gunship weapons-lasers; limited IRCM; non-lethal weapons technology/area denial; enhanced target identification.

Air Mobility Command

1. Airlift/Air Refueling: advanced IRCM.

GOALS

The goal of the Laser Technology thrust is to demonstrate and establish the feasibility and payoff of lasers for military applications and transition the technology to meet user needs. Specific goals include:

1. Demonstrate Chemical Oxygen-Iodine Laser (COIL) device scaling, high pressure operation, and extended run times for applicability to high power DEW systems, with emphasis on ground-based laser and ABL TMD missions.
2. Demonstrate scaling, packaging, weight reduction, and gravity-independent operation technologies to allow COIL devices to be used for ABL TMD missions.
3. Transition semiconductor diode laser sources, when suitable, to satellite crosslink communication developers.
4. Demonstrate and transition light-weight, compact, high efficiency semiconductor diode and diode-pumped lasers to meet customer needs in the areas of communications, remote and environmental sensing, terrestrial illumination, nonlethal weapons, medical applications, and countermeasures.
5. Develop advanced laser sources, e.g., new gas phase lasers; high repetition rate, ultra-short pulse lasers, etc., for high payoff applications where current laser source fail to meet application requirements.
6. Develop high power frequency agile sources in the near ultra-violet, visible and near infrared using nonlinear optical (NLO) processes. Demonstrate a 10 watt frequency agile laser system that uses multiple NLO processes. Identify, evaluate, and demonstrate innovative laser and space optical systems that are optimized to meet multiple mission requirements.
7. Conduct thermal and optical analysis supported by laser experimentation to assess and/or validate lethality and vulnerability effects against satellites and evaluate potential applications for GBL, ABL, SBL, and D^{2}IRCM programs.

MAJOR ACCOMPLISHMENTS

Progress in the single device program has resulted in 5 watts (continuous wave), diffraction limited output from a broad area emitter. Transition of these devices will continue to provide near-term application solutions for laser communications, remote/environmental sensing, and medical applications. These high-power single devices will also provide the building blocks for incorporation in array architectures to achieve very high powers. Ongoing contracts will develop high-power, coherent, fiber-coupled lasers with a goal of 10 watts, continuous-wave, diffraction-limited output power from a single-mode optical

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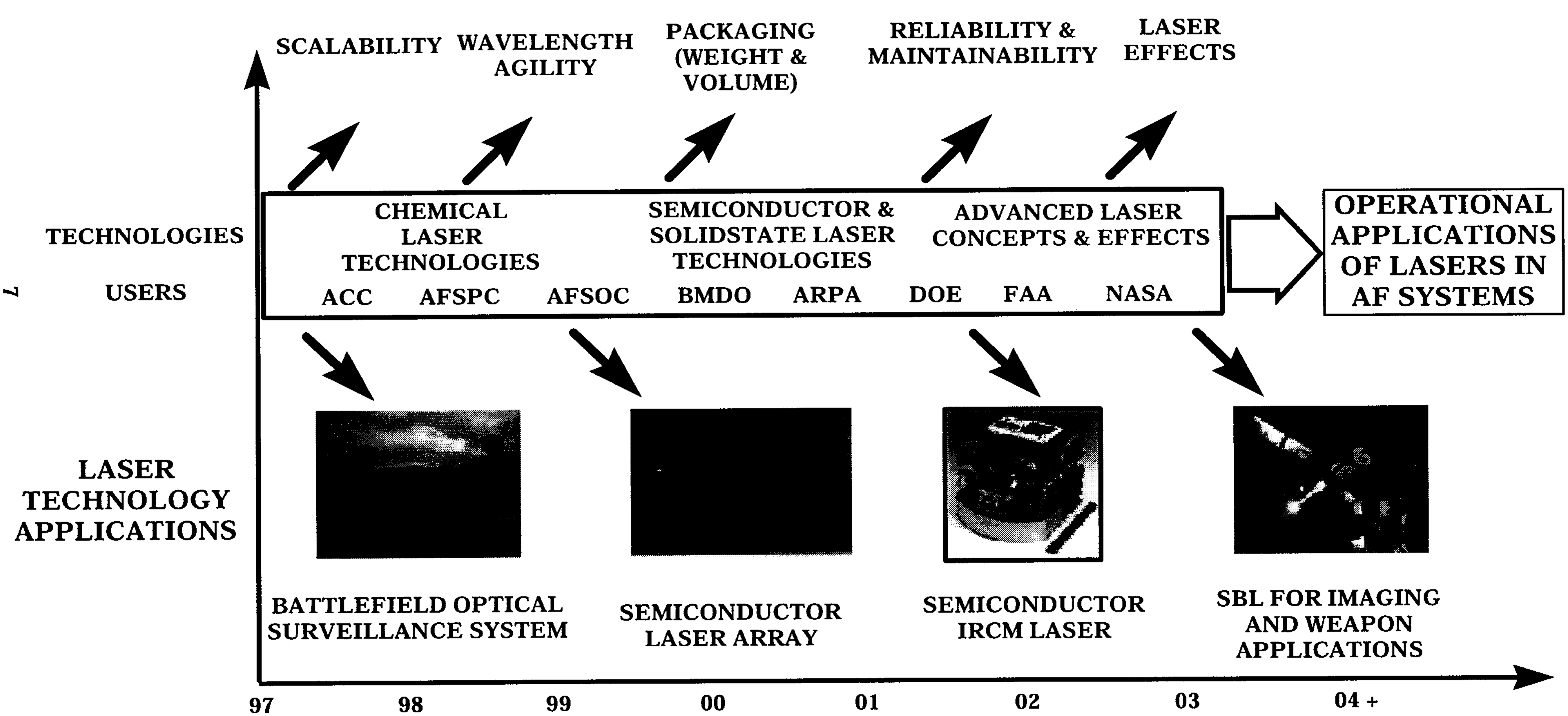
LASER TECHNOLOGY



fiber in FY99. Also, to further develop semiconductor laser technology, a BAA was released in FY96 for investigation of advanced concepts for improving semiconductor diode laser coherent power and beam quality.

Significant progress was made in FY96/97 in the area of high power semiconductor laser arrays and single devices. Over 180 watts of continuous wave, quasi-coherent output from an array of 64 elements was achieved. This demonstrated the feasibility of getting 200 watts of coherent output power by injection locking the array with a single master oscillator by FY99. These results will provide opportunities for semiconductor lasers to meet application requirements involving high power, including long range laser communication, optical countermeasures, area denial, high power illuminators for enhanced target identification, and DEWs.

The TRW Active Track Laser (ATLAS) has been installed at the Starfire Optical Range (SOR). Tests of this diode-pumped Nd:YAG device demonstrated nearly diffraction-limited performance at an average power in excess of 750 watts. The 1.06 micron output was frequency doubled to produce the highest average power solid-state green laser ever reported. The laser will greatly improve capabilities to do active tracking and compensation for atmospheric turbulence. ATLAS will be used in the illumination and tracking of satellites in support of the AFSPC space control mission.

An optically pumped semiconductor laser was sent to Wright Laboratory for testing as a candidate laser for the Large Aircraft IRCM program. This laser is an improved version of the one that was extremely successful in joint US/UK tests in FY96. Additionally, field tests of laser IRCM effectiveness at White Sands Missile Range were completed in FY96. The laser source created a spark within the missile and became the secondary source to jam and/or blind the seeker.

Subscale laser effects and lethality experiments were successfully completed on flexible and rigid solar array designs. Classified susceptibility thresholds were quantified in FY97 on these arrays. For ACC, lethality assessment studies on two high priority TMD targets for ABL and the effectiveness of D^2 IRCM concepts for aircraft self-protection were successfully completed.

Subscale testing provided the data necessary to demonstrate that the COIL laser will meet the PDRR goals of the ABL program. Under joint technology tests between PL and the two ABL contractors, the required chemical efficiency was demonstrated at the 10's of kW level and at power levels exceeding 100 kW. The results were based on generator technology efforts begun at PL almost ten years ago. Key to achieving the required chemical efficiency was to minimize the water production in the chemical generator. This was accomplished by developing ways to run the generators colder, thus producing less water vapor, and developing more efficient trapping techniques to remove the water that does leave the generator. In addition, new forms of Basic Hydrogen Peroxide (BHP) solutions were used in the anticipated ABL conditions without producing undesirable salts. This has been a problem for the last several years.

Assessments have been completed on twelve foreign and domestic satellites, including laser induced thermal and optical vulnerability and lethality analysis. This physics based analysis was anchored by numerous laser effects experiments on satellite components and materials. High fidelity models of over a dozen additional satellites were also produced and are currently being assessed. Support was provided to USSPACECOM's Laser Clearinghouse and the Airborne Laser (ABL) program office in determining the vulnerability and susceptibility level of sensitive optical components aboard satellites that might be inadvertently illuminated by DoD lasers. A study was conducted that showed the probability of inadvertent illumination of satellites by ABL was low, but that optical components could be damaged.

CHANGES FROM LAST YEAR

The Nonlinear Optics Technology FTA (A1D01) was eliminated with the work split between the Lasers and Imaging Thrusts (Thrust 1 & 3). Additionally Thrust 5, Space Control, was eliminated with the Laser Effects projects incorporated into the Advanced Lasers Concepts FTA of this thrust.

MILESTONES

Several recent studies have identified the enormous potential of lasers and optical systems in space for global virtual presence, and for precision engagement anywhere in the world, anytime to support the Full-Spectrum Dominance envisioned by the Joint Chiefs of Staff. The Lasers and Space Optical Systems (LASSOS) program has initiated a study to focus on the AF missions of Space Control, Space Force Applications, and Space Force Enhancement. The LASSOS study will identify promising technology concepts for space laser systems, develop system concepts that are optimized for multiple missions, and suggest R&D programs for the FY00 POM.

The development and demonstration of COIL device technology to meet the requirements of near-term HEL applications, such as GBL and ABL TMD, requires improvements in

chemical efficiency and size and weight reduction. Current work with the advanced diagnostics will lead to avenues for further improvements in chemical efficiency. Also being examined are more fieldable forms of Basic Hydrogen Peroxide. Additionally, the development of a COIL based illuminator is required for risk reduction for the ABL and GBL systems. Current work will include examining the development of high average power frequency conversion, the incorporation of an unstable resonator on the RADICL device and gain switching of RADICL. These efforts will continue through FY97 and FY98.

Single semiconductor laser diode technology development continued in FY97 to obtain devices with up to 10 watts continuous output and good beam quality. These devices will be transitioned to meet near-term user needs.

Efforts to understand the mechanisms generating TeraHz radiation in InSb by sub-100 femtosec laser pulses have been completed. Also, the first observation of the carrier dynamics in HgCdTe with various compositions, has been accomplished. Building on these successes, extension of these studies into the 2-5 micron region will continue. Fourier Transform Spectroscopy experiments involving the TeraHz radiation are ongoing. Propagation of these ultra-short laser pulses will continue. Radiative effects experiments and investigations are scheduled to continue through FY00. Various nonlinear methods are being investigated with the goal of producing, by FY02, a high power source (1000 W) operating from the near-ultraviolet through the visible to the near-infrared wavelength region.

Vulnerability studies to assess the effectiveness of the ABL in adjunct missions are continuing. The adjunct missions include protection of high valued assets, Suppression of Enemy Air Defense (SEAD), and cruise missile defense. Additionally, the evaluation of laser induced contamination of spacecraft components is progressing through FY97/98 in support of GBL and SBL programs. The results will yield criteria for causing temporary or permanent degradation of spacecraft.

THRUST 2: BEAM CONTROL

USER NEEDS

Beam control technology is central to the realization of essentially all applications of laser and optical imaging systems, because the beam control system functions to deliver the beam from the laser device to the transmitting aperture, correct for optical and atmospheric-induced distortions, acquire and track the intended target, and point the beam to the designated target aim point. Combined with the appropriate laser sources or imaging sensors, this thrust supports the following user needs, as stated in current Mission Area Plans:

Air Force Space Command

1. Counterspace/Space Control: counterspace (negation) capability -
2. Command & Control/Force Application: no current weapon systems - high energy lasers.
3. Space Surveillance: limited space intelligence support (SOI, MPA, imagery, status assessment).

Air Combat Command

1. Theater Missile Defense: attack and kill capability - Airborne Laser (ABL).

GOALS

The goal of the Beam Control thrust is to develop and transition advanced optical systems and technologies for both laser propagation and high resolution imaging applications. This includes efforts to:

1. Establish the technology base for atmospheric compensation for applications such as GBL, ABL TMD, and imaging for incorporation into systems in the late 90's and for planned improvements in the 2002 time frame.
2. Develop and demonstrate critical optical acquisition, tracking, and pointing technology for high energy laser systems to stabilize and point the beam to a selected aimpoint and to stabilize the image plane for optical imaging applications such as space object identification.
3. Develop and demonstrate key high energy laser optical component technologies to enable advanced weapon applications.
4. Develop and validate the modeling and simulation tools needed for accurate performance and mission effectiveness assessments.

MAJOR ACCOMPLISHMENTS

Field experiments at Starfire Optical Range (SOR) have continued to evaluate adaptive optics and tracking hardware in a field environment and to develop and upgrade the hardware for future demonstrations. In early FY97, a field test series called the Tilt Anisoplanatism Measurement experiment (TAME) was performed on the SOR 1.5 meter telescope. The experiment used binary stars to demonstrate closed-loop, real-time compensation for tilt anisoplanatism, a degrading effect of atmospheric turbulence which is manifested as a track jitter error. Because the out-going laser beam must be aimed ahead of the apparent position of the satellite, the track jitter sensed by a satellite tracking system is not in exactly the right direction. The error introduced by improperly sensing the tilt component of turbulence distortions is referred to as tilt anisoplanatism. Future experiments will include demonstration of tilt anisoplanatism compensation on satellites.

Active (laser illuminated) tracking of retro-reflector equipped satellites with simultaneous compensated imaging was demonstrated at the SOR. This was a significant step toward a 24-hour tracking capability. In January 1997, a new, high beam quality 750W Nd:YAG laser was integrated with the SOR 1.0 meter laser beam director. This laser will provide the ability to continue active tracking experiments using satellites not equipped with retro-reflectors.

Installation of the new adaptive optics system for the SOR 3.5m telescope is expected to be complete by the summer of FY97. This is a 941-channel system, compared to the existing 241-channel adaptive optics at the 1.5 meter telescope. System tests, including compensated imaging experiments using astronomical objects will follow immediately. No laser beacons will be involved in the initial experiments.

The Airborne Laser (ABL) Technology subthrust proceeded from concept validation and risk reduction, in which criteria to support Milestone I for the ABL program were paramount, to advanced concept exploration to

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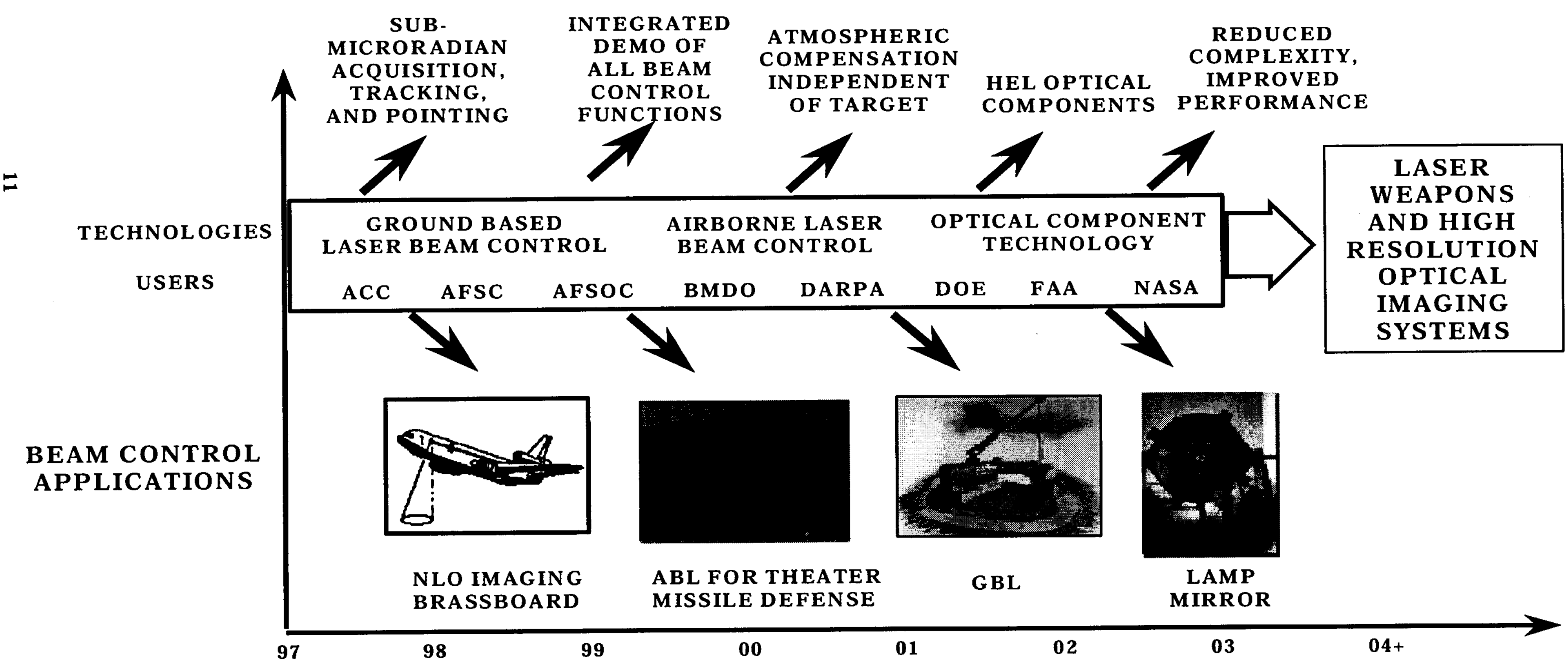
BEAM CONTROL



improve ABL performance. Milestone I for ABL was successfully passed in November 1996, concluding questions on the maturity of critical criteria: laser power and scalability; atmospheric turbulence characterization, active compensation performance, and active tracking of boosting missiles. These same criteria remained prominent concerns for the program's first Authority to Proceed (ATP-1) scheduled for summer 1998. The beam control thrust closed two of four ATP criteria (active compensation and active tracking) successfully in FY96 and early FY97, and is contributing to closure on the atmospheric data base.

Prior atmospheric measurements from ABLE-X (FY93) and ABLE-ACE (FY95) verified that statistics for at-altitude atmospheric turbulence essentially obeyed theoretical (Kolmogorov) projections. These important experiments indicated the PL/GP CLEAR I turbulence model for ABL scenarios, and the basis for ABL development were sound. Milestone I recognized the validity of these conclusions. Collection of atmospheric data will proceed through FY97 and 98, filling in a world-wide data base to validate the application of ABL models to global combat capability. Characterization of the turbulence in two operational theaters (Korea and the Mid-East) is proceeding for each quarter of FY97 and FY98. ABL SPO personnel will use technical assistance from the Phillips Laboratory Geophysics and Lasers and Imaging Directorates for aircraft and balloon-borne measurements to build a robust database of turbulence measurements to characterize the obstacles to full ABL capability. The first of these joint measurements occurred in late April 1997. In addition, S&T assets will be conducting joint balloon-borne, aircraft, and radar tests at White Sands Missile Range in late FY97 to verify the statistical correlation of these measurements, and anchor turbulence models in three dimensions.

Active tracking of a theater ballistic missile (including plume-tracking, illumination, and hand-over) was successfully demonstrated in a joint AF/Army test at WSMR in late FY96 and early FY97. The active track test, against a Black Brandt missile, was demonstrated four times, using the Navy's Sea-Lite Beam Director (SLBD), modified by Phillips Lab personnel. This demonstration, and the ensuing report, closed early one criterion (active track of a boosting missile) for ATP-1. Advanced tracking concepts will be necessary to extend this capability to further ABL lethality. Early construction and experimentation have begun to establish an Advanced Tracking Laboratory at Kirtland AFB to test and refine tracking algorithms and hardware for inclusion on later ABL platforms. The advanced tracking laboratory will reach initial operational capability in FY98.

Simultaneous active tracking and active compensation are the fourth of four criterion for ATP-1 to be passed. Tests at MIT Lincoln Laboratory's Firepond test range have been exploring this concept and conclude in late May, 1997. Once these tests have concluded, and data to support ATP-1 gathered, equipment will be transferred to support an Advanced Compensation Laboratory at MIT/LL facilities on Hanscom AFB.

Both the Advanced Compensation Lab and the Advanced Tracking Lab will conceptualize and explore risk reduction and performance enhancement ideas to further ABL performance. The remainder of the FY97 effort and most of FY98 will involve standing these laboratories up and completing construction on the ABL-scaled testbed to be located at North Oscura Peak on WSMR. Construction on this 1/6 ABL-scaled site will begin in late FY97 and proceed to active tracking of missiles-of-opportunity in late FY98. This testbed will be used to verify innovative beam control systems to gain significant improvements in ABL performance--two to five times better engagement time and range have been predicted for some proposed improvements.

During late FY96 and early FY97, a 37 inch diameter optic was coated at the PL Optical Coating and Component Evaluation Laboratory (OCEL) for LANL. The process for deposition of ZrO_2 was successfully scaled for use in the large coating chamber to meet the requirements of this unique coating design. A large, 22 inch window was also coated in the OCEL in support of an SOR experiment. In addition to the successful completion of these large area coatings, several coatings were also deposited for other PL projects.

The use of Ion-Assisted Deposition (IAD) to further reduce the scatter and improve the durability of coatings was also initiated during the past year at the OCEL. Studies of single layer films are on-going, but preliminary results indicate a substantial reduction in scatter for some oxide coating materials.

MILESTONES

This thrust results in full-scale demonstrations of GBL beam control technologies

through FY00. Installation of a 941-channel adaptive optics system for the 3.5 meter telescope and the first demonstration of star-loop atmospheric compensation performance will be completed in FY97. Key FY97 experiments will include compensated imaging of both astronomical objects and satellites, followed by compensated low-power laser propagation. Active tracking of dim satellites without retro-reflectors will be done in late FY97. Work in parallel on tracker upgrades, aim point designation and control algorithms, and improved satellite acquisition methods will be incorporated, leading to full-scale, low-power field tests of acquisition, tracking, and pointing technology appropriate for GBL applications in FY98-99. The performance metrics are the residual tracking error and the beam pointing accuracy which can be achieved against realistic satellite targets.

The final demonstrations for GBL beam control will emphasize integrated performance of the overall beam control system, including all the functions necessary for a satellite engagement (acquisition, tracking, pointing, and atmospheric compensation). The goal is to demonstrate integrated performance which meets the requirements for a full-scale GBL system, thereby establishing the maturity of beam control technology for these applications.

Dynamic tests of tracking concepts and algorithms were completed at White Sands Missile Range. This set of experiments represented the first ever active track demonstration against full-scale theater ballistic missiles. The technology demonstration, against four Black Brandt missiles closed one of the final Milestone I criterion. Simultaneously the experiment closed, 1 ½ years early, a critical Authority to Proceed criterion. This proof-of-concept was a major risk mitigation effort for the ABL.

Active compensation efforts by Phillips Laboratory and MIT Lincoln Laboratory personnel have thoroughly established the maturity of traditional adaptive optic methods to compensate for atmospheric distortion to the degree necessary for ABL lethality. This technology demonstration also closed early (by one year) an ABL risk mitigation criterion.

In long range technology demonstration programming, the preliminary and critical design reviews for the North Oscura Peak testbed proceeded on schedule in February and May respectively, of FY97. This ABL Advanced Concepts Testbed (ABL ACT) will be used as a 1/6 scale model for ABL improvements. Proposed testing, both in-house and by ABL-team contractors, will proceed in late FY98 in time to field improved compensation techniques on the PDRR version of the ABL.

The demonstration of a bonding technique for fused silica cooled optics, and identification of a non-toxic coolant is to be completed during FY97. Cooled transmissive optics may be required for beamsplitters or other high energy density window applications.

THRUST 3: IMAGING

USER NEEDS

This thrust supports the following mission areas and associated technology needs or deficiencies, as provided in the current Mission Area Plans (MAPs), through the development of advanced imaging and remote sensing techniques. Involved are passive and active (laser illumination of targets) methods to improve the resolution, extend the time availability, and reduce turn-around time for space surveillance data. Conventional and nonconventional methods are being developed to increase the information obtainable by the optical observation system and to increase the range from low earth orbit (LEO) to geosynchronous (GEO) altitudes. Additional efforts address the improvement of airborne and space-based imaging systems.

<u>Air Force Space Command</u>

1. Space Surveillance: Inadequate continuous near earth coverage; limited space intelligence support; limited coverage, multi-phenomenology; SOI, MPA, imagery, status assessments.
2. Command and Control: Surveillance coverage; deep space surveillance.

<u>Air Force Special Operations Command</u>

1. Joint Air-SOF Battlefield Interface: No real/near real-time information from national systems.
2. Force Application: No real-time information for target study; no en-route real time information; enhance target identification capability.
3. Psychological Operation: No real/near real-time information from national systems.

<u>Counterproliferation</u>

1. Includes Air Combat Command, Defense Intelligence Agency, and the CINCs.
2. Long Range (>100km) detection & identification of development, production, and test of weapons of mass destruction.
3. Detection and identification of illicit drug production.
4. Long range detection and characterization of battlefield use of weapons of mass destruction.
5. Battle Damage Assessment: Assess damage & need for follow-up strikes against underground storage facilities for weapons of mass destruction.

GOALS

The goals of the Imaging Thrust are to develop and transition advanced optical systems and multi-spectral sensing technologies for tactical and/or strategic applications to meet user needs in the areas of quality optical imagery and remote sensing. Specific goals include:

1. Develop active imaging techniques to obtain images of LEO objects, and extend these technologies to reach deep space or GEO objects.
2. Develop technologies for lightweight space optics, scene based wavefront sensing, electro-optical (EO) adaptive optics and on-board image processing.
3. Develop passive imaging techniques to obtain images of LEO objects, and extend these technologies to reach deep space or GEO.
4. Develop advanced EO devices to support other AF missions, including long range laser target designators, optical reconnaissance and surveillance of chemical and biological weapons in production or in use on the battlefield.
5. Develop nonlinear optical systems to automatically correct for dynamic optical errors introduced by the atmosphere, and to correct for static errors to very large diameter, lightweight, deployable primary mirrors on imaging satellites.
6. Evaluate multi/hyper- spectral, thermal, radiometric sensor technologies for space applications; develop parallel processing technologies for real-time image analysis; develop high-resolution, ground-based optical imaging technology and signature data collection capabilities for detailed threat assessments; develop advanced intelligence data analysis technologies for spacecraft sensor data fusion and identify advanced methods to exploit all-source intelligence data; and develop simulation and display technologies for realistic training and exercise support for operators.

MAJOR ACCOMPLISHMENTS

Several major accomplishments during the past year have contributed significantly toward the achievement of technical goals and addressing stated user needs and deficiencies. These

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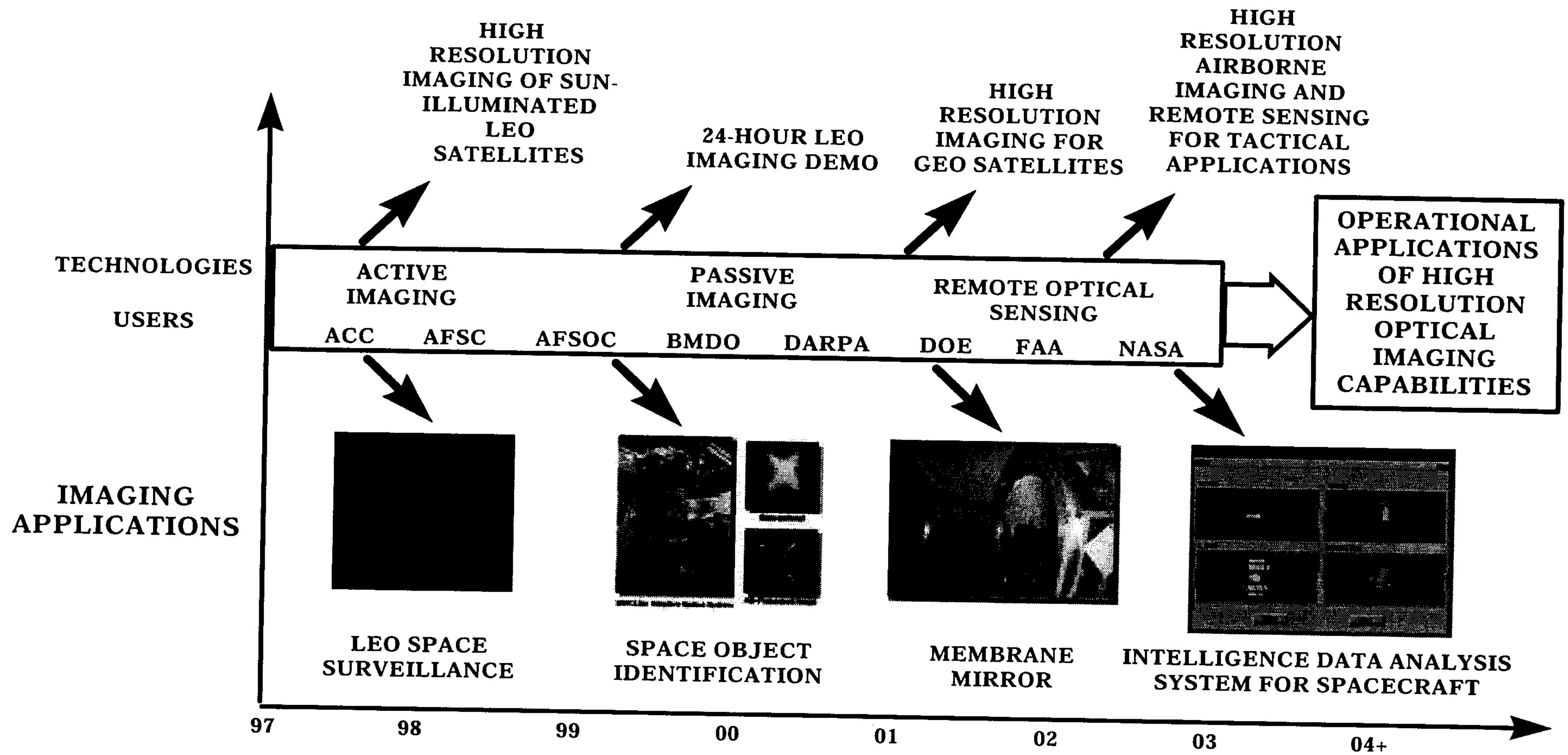

accomplishments range from the successful completion of laboratory proof-of-principle experiments to the demonstration of techniques in realistic field experiments.

The High performance CO_2 LADAR Surveillance Sensor (HI-CLASS) laser operated in the LIDAR mode, April 97, on the top of Mt. Haleakala, Maui, HI. Directing the laser at a ground site 18 km away, liquid trichloroethelyne was detected – the first time a liquid has been used in the test cell. HI-CLASS is currently operating at 30J, 30Hz and primarily supports Space Object Identification (SOI) efforts for AFSPC, but the high altitude of Mt Haleakala makes it possible to simulate a LIDAR on an aircraft for experiments supporting counter-proliferation and drug inter-diction.

The Argus team successfully supported the Defense Special Weapons Agency's Dipole Tiger 1 tests at White Sands Missile Range (WSMR). The tests simulated bombing of a chemical weapons bunker to study propagation of chemicals. The Argus wide and narrow field cameras recorded the explosion and the Nonproliferation Airborne LIDAR Experiment (N-ABLE) detected and tracked gaseous effluent from the debris. This test provided excellent results and evaluated methods of locating and tracking chemical clouds from an uncooperative target.

The Space Based Imaging Program continues research of large, high resolution, lightweight imaging systems for geosynchronous orbits. A meter-class laboratory breadboard for use in the characterization of nonlinear optical (NLO) and electro-optical (EO) wavefront correction techniques was successfully constructed. The breadboard includes a lightweight primary mirror that can be deformed in a controllable manner to meet expected figure conditions for a sensor satellite. The NLO correction technique will be demonstrated in a lab setting by 1Q FY98, followed by an EO demonstration by 3Q FY98.

Also within the Space Based Imaging Program, a new membrane mirror for space-based imaging applications has been designed. This design is specifically made to address various optical imaging issues associated with membrane mirrors. The present design will be improved in order to build a meter-class membrane mirror. This meter-class membrane mirror can then be tested in the above mentioned laboratory breadboard.

Construction and testing of an airborne brass-board for the MightySat II.1 hyperspectral pay-load was completed within the spectroradiometry program. The spaceborne payload has been designed and we are now building the sensor and developing analysis capability in anticipation of an FY99 launch. Polarimetric sensors and analysis techniques are being developed for a MightySat follow on system to be launched in FY01 or FY02.

The active remote sensing program has field tested the N-ABLE system. A longer range version, called Laser Airborne Remote Sensing (LARS) is being integrated in FY97 and will be tested in FY99.

The Intelligence Data Analysis System for Spacecraft (IDASS) - Phase II of five year, four phased IDASS program, was installed and demonstrated within the USSPACECOM's Combined Intelligence Center (CIC). This years' development demonstrated more advanced exploitation capabilities and linkage to additional space surveillance collection assets.

CHANGES FROM LAST YEAR

Limited funds for active imaging programs has resulted in stretching the programs into FY98. U.S. Pacific Command and AFSPC have both increased the level of processing on the supercomputer. AFSPC has continued progress on transitioning the Maui Space Surveillance Site to total operational control and has officially accepted the site as an operational entity.

This year the NLO research was combined with the Space Based Imaging Program. The continued research into membrane and active optics has made the integration of smart sensors for beam control and wavefront control necessary. The program's goal is the development of technologies for a high-resolution, lightweight optical sensing satellite. Tasks include: characterization of deployable, inflatable primary mirrors, NLO and EO correction techniques for use on ultra-lightweight, low quality telescope optics, and smart optical sensors for figure control, active control, and image processing.

The Imaging Applications FTA (A3A06) was eliminated with the work added to the Advanced Imaging Concepts FTA (A3A05).

The IDASS subtask from Thrust 5 has been moved into this thrust.

MILESTONES

A passive technique, compensated daylight imaging, builds upon the results of field tests at Starfire Optical Range and on improved image processing algorithms, and was used to demonstrate imaging of ultra-dim objects in FY97 at MSSS. By mid-late FY97, the upgraded Observatory Control System was completed and transitioned to AFSPC, allowing for improved operation at the site. Continuing developments in sensor and adaptive optics systems also provided the technology for an improved operational capability at the Advanced Electro-Optical Sensor (AEOS). The 3.67 meter primary mirror for the

AEOS telescope was successfully coated at Kitt Peak Observatory in Feb. 97, with installation at the Maui facility in April 97. The system will be completely operational in FY99 after delivery and installation of the required sensors.

Another effort, funded through a Congressionally-directed initiative, is the development of an Active Imaging Testbed. With continued funding support, the completion of illuminator laser development, the integration of optical receiver hardware, and the demonstration of a limited active imaging capability is planned for the end of FY97. Follow-on experiments will refine LEO imaging techniques. Subsequent active imaging work will extend the capability to GEO targets, with anticipated start of tests during FY00.

A full capability Hi-CLASS laser radar system is expected to be on line at MSSS during FY97. This system will be used to demonstrate Doppler imaging of LEO satellites and evaluate the potential for space debris detection and sampling.

Airborne hyperspectral measurements and LIDAR demonstrations in FY97 support the development and demonstration of an airborne testbed for active remote sensing for reconnaissance and surveillance of chemical weapons in production or use on the battlefield.

Milestones within the Space Based Imaging Program include an FY98 laboratory demonstration of EO correction of figure errors in a meter-class, lightweight primary telescope mirror; an FY99 start for design and construction on a lightweight imaging satellite optical brassboard mock-up to be tested and space qualified in a NASA provided space environment simulation facility; and an FY02 start of space experiments.

Intelligence Data Analysis System: The IDASS Phase IV is scheduled to be delivered to CIC in the 3Q98.

THRUST 4: HIGH POWER RF TECHNOLOGY

USER NEEDS

This thrust supports the Air Combat Command (ACC), Air Mobility Command (AMC), Air Force Special Operations Command (AFSOC), and Air Force Space Command (AFSPC) mission areas and associated technology needs or deficiencies as provided in the current Mission Area Plans (MAPs). The needs listed below have been examined by the Product Centers' Technical Planning Integrated Product Teams (TPIPT)s, and documented in their Technology Investment Recommendation Reports (TIRR)s.

1. Counter Surface-to-Air & Air-to-Air Missiles
2. Large Aircraft IR Countermeasures
3. Suppression of Enemy Air Defenses
4. Air Interdiction of C^4I Defenses
5. Degrade Enemy Air Control
6. Degrade Enemy Military Base Operation
7. Reduce Enemy Sortie Generation
8. Hardened Target Weapons
9. Agent Defeat Warheads
10. Less-Than-Lethal Weapons
11. RF Disruption of Electronic Systems

RF Effects and Hardening is a pervasive need driven by requirements at several different levels. The Operational Commands and Air Logistic Centers (ALCs) have articulated their user level needs for RF Effects Systems Survivability. The Phillips Lab is the prime executor of high power RF effects and Hardening programs, and, as required, supports customers in more general EMI/EMC efforts.

AFSPC Space Control requirements are taken from the Space Surveillance, Counterspace and Missile Defense MAPs. SMC requirements derive directly from the AFSPC Space Control MAPs. Needs supporting these areas are listed below:

Counterspace Protection
1. Attack and Fault Detection Sensors
2. Satellite Threat Warning/Attack Reporting
3. Natural and Threat Environment Protection of EO and RF Systems
4. Active Protection Technologies

Missile Defense
1. Decision Support Systems
2. Enhanced Data Fusion Technology
3. Survivability Techniques

GOALS

The overall goals of the High Power RF Technology thrust are to develop and transition high power RF technology into the operational inventory, and to protect US systems against the expanding threat represented by similar foreign systems. Also, the primary goal in surveillance and protection is to develop advanced technologies to improve operational force capabilities for maximizing situation awareness, accelerating the decision and tasking process, and protecting US and Allied space systems.

The *Weapons Applications* portion of this thrust is organized under four Mission Application programs which perform research in response to user needs. The goals under these programs seek to provide revolutionary rather than incremental advances in the force capabilities. The four programs and their goals are:

1. HPM Aircraft Self Protection (ASP)
   - Develop technology for wideband HPM Countermeasure (CM) to protect aircraft against Infrared (IR) and other precision guided missiles in a non-system specific manner.

2. HPM Suppress Enemy Air Defenses (SEAD)
   - Suppress enemy air defenses and burn out electric components within an enemy's Integrated Air Defense System (IADS).

3. HPM Command Control Warfare (CCW)
   -Temporarily or permanently render C^3 installations inoperative.

4. RF Active Denial Technology (ADT)
   -Demonstrate and transition RF Active Denial Technology

The *Source Components* goal is to provide Directed Energy Weapons Programs with pulsed power, RF sources and antennas, and sources for effects measurements.

The *RF Effects and Hardening* goal is to develop the capability to determine microwave frequency susceptibility and hardening requirements for specified systems and subsystems.

The *Assessments and Survivability* specific technology goals are:

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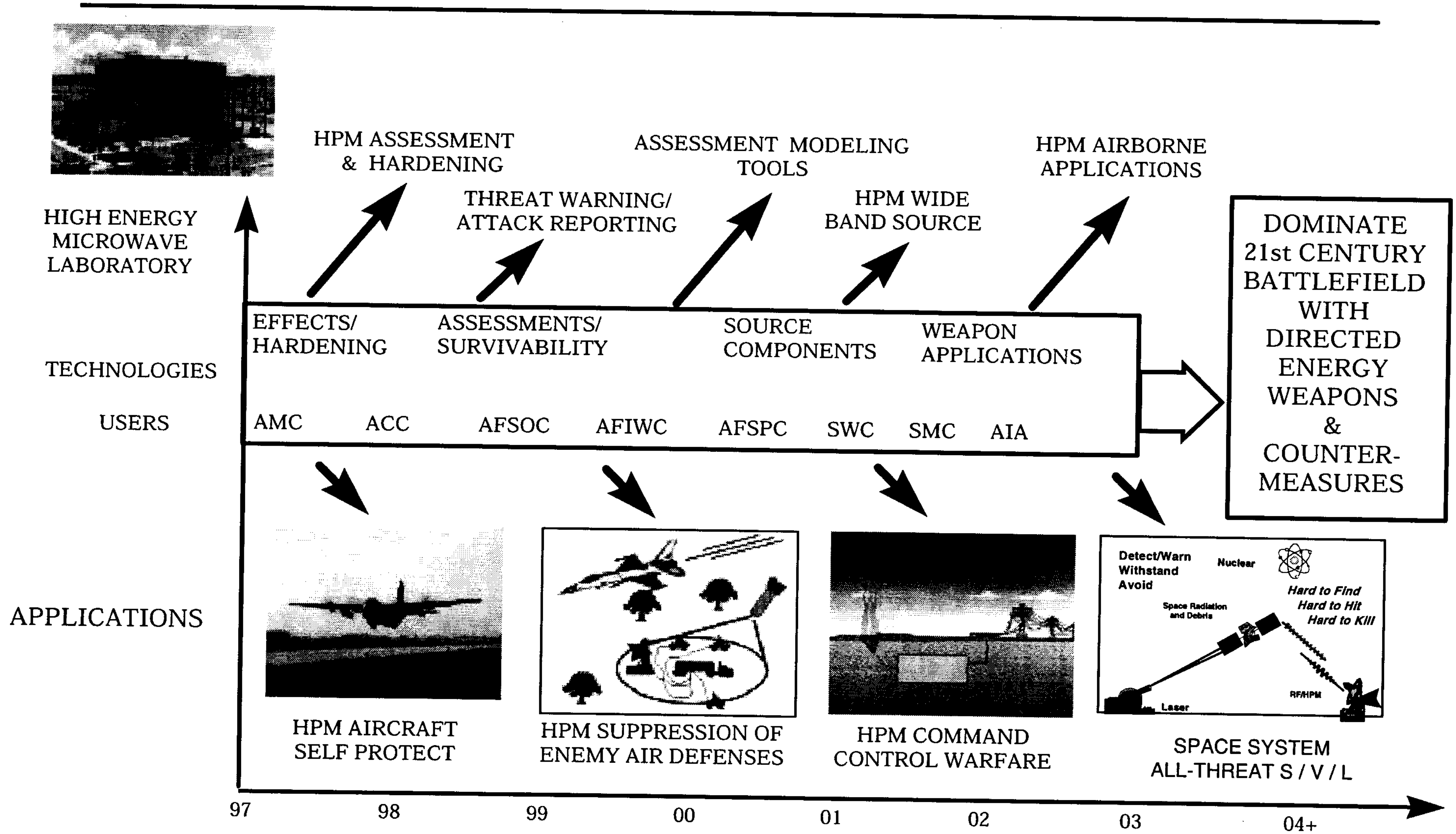
HIGH POWER RF TECHNOLOGY



1. Counterspace Protection: Develop threat warning and attack reporting architecture and enabling technologies. Develop techniques to make materials capable of withstanding the effects of electromagnetic, and other advanced weapon attacks. Develop technology solutions that help prevent enemy use of US space systems. Develop advanced all-threat satellite response modeling and assessment capability. And identify, evaluate, demonstrate and transition high-data rate, survivable communications technologies, along with near real-time DEW deconfliction technologies..
2. Missile Defense: Quantitatively assess the effectiveness of RF weapons against missile borne weapons; develop technologies for sensor data fusion and image simulation; develop simulation and display technologies for training and exercise support; enhance and apply all-threat modeling; develop Battle Damage Assessment (BDA) technologies for assessments and rapid decision support.

The result is a fully integrated approach to RF Systems Effects, Vulnerability, and Lethality, covering natural, inadvertent man-made, and potential hostile RF weapons threats.

CHANGES FROM LAST YEAR

RF Weapons was reorganized during FY 97 to include technology areas from Thrust 5 which was eliminated. Space Debris was transferred entirely to the Space & Missiles Tap. A new subthrust, Assessments and Survivability, was created to incorporate the remaining areas. The RF Space Control area was phased out due to funding cancellation. The Laser Effects effort was transferred to Thrust 1, Laser Technology and IDASS was transferred to Thrust 3, Imaging.

MAJOR ACCOMPLISHMENTS

HPM Sources: Some notable achievements during the previous year: World Records Set

1. The Relativistic Klystron Oscillator (RKO) design set a record for total energy radiated, power radiated and efficiency: 1.5 Gigawatts (GW) and total energy extracted of 170 Joules. This results in a significant cost and weight savings for the device.
2. The Magnetically Insulated Line Oscillator (MILO) also set a world record with a power extracted of 2.0 GW and total energy extracted of 300 Joules.
3. Also, some of the first future weapons' energy sources were tested. Known as Magnetocumulative Generators (MCG)s, over 25 successful explosive shots were conducted at the High Energy Research & Test Facility (HERTF). Currents approaching 750 Kiloamps (kA) were generated from a 22 kA initial current.

HPM Antenna development:

1. Coaxial Beam Rotating Antenna (COBRA):
 - A brassboard design of the COBRA was demonstrated which will be used with several HPM sources. The COBRA is one of a number of HPM antenna designs which combine mode conversion and beamwidth control into one compact device.
2. Ultra Wideband (UWB) High Voltage Horn Antenna:
 - Researchers successfully demonstrated a new design in UWB antennas. The new horn design incorporates several novel concepts including a Point Geometry Mode Converter capable of sustaining up to 13 megavolts per centimeter and a Brewster Angle window to transition the high voltage pulse from oil to air.
3. Lensed Horn UWB Antenna:
 - The theory and concept for two UWB antennas designed to radiate and receive extremely short transient waveforms at high levels of voltage was developed. Both antennas were demonstrated to have flat frequency spectra ranging from 500 MHz to 30 GHz and to be capable of radiating with a risetime of 23 picoseconds. These antenna designs have greatly improved the performance of underground radar and ground penetrating weapons.

New Parallel Codes Developed:

1. A new parallel , 3D Particle-In-Cell code called "Icepic" was developed and now allows simulation of devices such as HPM generators yielding more efficient valuable design information.
2. A new Phased Array Antenna Analysis (PARANA) software was developed. PARANA provides a new capability to accurately predict the electromagnetic (EM) properties of general periodic structures. This gives more accurate antenna designs, and prediction of EM penetration through conducting screens, reinforced concrete, and fiber composites.
3. A parallel, 3D Magneto Hydrodynamic Code, MACH3, was rewritten for parallel-processor super computers. For the first time, the real-world case of 3D simulation of magnetofluid is obtainable.

Assessments and Survivability

1. First Time Multiple Space Threat Testing of Detector Array - The survivability group performed experiments at its High Frequency Microwave Facility measuring for the first time a detector's response to "multiple

threats". These experiments will ultimately lead to satellite-borne sensors which will perform effectively in hostile environments.

MILESTONES

The technology activities of the High Power RF Technology Thrust are converging on several mission applications culminating in a series of CEs and ATDs during the next five years. The most critical program milestones are associated with generating the RF effects requirements database, demonstrating candidate HPM sources, and integrating the down-selected systems into practical packages for the mission applications. Although the Metrics associated with these milestones are classified, the calendar of major events are listed below:

1. Suppression of Enemy Air Defenses (SEAD)
   - Complete Critical Experiments 4Q98
   - Complete ACTD 4Q00
2. Aircraft Self-protect
   - Sub-scale source for static field test- 4Q97
   - Full scale source for live fire field test 4Q98
3. Active Denial Technology
   - Ground phased demo 4Q99
4. Command & Control Warfare:
   - Advanced Concepts Technology Demo in FY98 with strong user/OSD support.
5. RF Effects & Hardening:
   - Phase 1 & 2 Orlon Fiber Effects Experiment - 4Q97
6. Threat Warning/Attack Reporting:
   - Commercial microbolometer evaluation 4Q97
7. Assessments:
   - Complete multi-threat CCD/telescope demo - 4Q97
   - Evaluate composite material impact on S/C EM properties - 4Q97
8. Protection Technologies:
   - Integrate protection technology state of the art data in sensor model - 4Q97

GLOSSARY

A

ABL — Airborne Laser
ABL ACT — ABL Advanced Concepts Testbed
ABLE-ACE — Airborne Laser Extended Atmospheric Characterization Experiment
ABLE-X — Airborne Laser Extended Experiment
ACC — Air Combat Command
ADONIS — AMOS Daytime Optical Near-Infrared Imaging System
ADT — Active Denial Technology
AEOS — Advanced Electro-Optical System
AFAE — Air Force Acquisition Executive
AFIWC — Air Force Information Warfare Center
AFMC — Air Force Materiel Command
AFMC/ST — Director of Science and Technology
AFOSR — Air Force Office of Scientific Research
AFSOC — Air Force Special Operations Command
AFSPC — Air Force Space Command
AIA — Air Intelligence Agency
AIT — Active Imaging Testbed
ALC — Air Logistics Center
AMC — Air Mobility Command
ART — Aircraft Radar Turbulence
ASP — Aircraft Self Protection
ATD — Advanced Technology Demonstration
ATLAS — Active Track Laser
ATP-1 — Authority to Proceed
ATP — Acquisition, Tracking & Pointing

B

BAA — Broad Area Announcement
BDA — Battle Damage Assessment
BHP — Basic Hydrogen Peroxide
BOSS — Battlefield Optical Surveillance System

C

CCW — Command and Control Warfare
C^3I — Command, Control, Communications, and Intelligence
CE — Critical Experiment
CIC — Combined Intelligence Center
CM — Countermeasure
COBRA — Coaxial Beam Rotating Antenna
COIL — Chemical Oxygen-Iodine Laser
CRDA — Cooperative Research and Development Agreement

D

D^4 — Deny, Disrupt, Degrade, Destroy
DEW — Directed Energy Weapon
DOD — Department of Defense
DOE — Department of Energy

E

EM — Electromagnetic
EMI — Electromagnetic Interference
EMC — Electromagnetic Compatibility
EO — Electro-optical

F

FAA — Federal Aviation Administration
FTA — Focused Technology Area

G

GBL — Ground-Based Laser
GEO — Geosynchronous
GHz — GigaHertz
GW — GigaWatt

H

HEL — High Energy Laser
HEML — High Energy Microwave Laboratory
HERTF — High Energy Research & Test Facility
Hi-Class — High Performance CO_2 LADAR Surveillance Sensor
HMMV — Highly Mobile Military Vehicle
HPM — High Power Microwave
Hz — Hertz

I

IADS	Integrated Air Defense System
IDASS	Intelligence Data Analysis System for Spacecraft
IR	Infrared
IRCM	Infrared Countermeasures

J

J	Joule
JDL	Joint Directors of Laboratories

K

kA	Kiloamps
KEW	Kinetic Energy Weapons
km	kilometers
kW	kiloWatts
kHz	kiloHertz

L

LADAR	Laser Detection and Ranging
LANL	Los Alamos National Laboratory
LARS	Laser Airborne Remote Sensing
LASSOS	Lasers and Space Optical Systems
LEO	Low Earth Orbit
LIDAR	Light Detection and Ranging
LIME	Laser Induced Microwave Emission
LLNL	Lawrence Livermore National Laboratory
LPD	Low Probability of Detection
LPI	Low Probability of Intercept

M

m	meter
MajCom	Major Command
MAP	Mission Area Plan
MCG	Magnetocumulative Generator
MILO	Magnetically Insulated Line Oscillator
MOA	Memoranda of Agreement
MOU	Memoranda of Understanding
MPA	Mission Payload Assessment
MSSS	Maui Space Surveillance Site
mW	milliWatt
MW	MegaWatt

N

N-ABLE	Nonproliferation Airborne Lidar Experiment
NASA	National Aeronautics & Space Administration
NATO	North Atlantic Treaty Organization
Nd:YAG	Neodymium Yttrium Aluminum Garnet
NLO	Nonlinear Optics

O

OSD	Office of the Secretary of Defense

P

PARANA	Phased Array Antenna Analysis
PL	Phillips Laboratory
PMD	Program Management Directive

R

R&D	Research & Development
RADICL	Research Assessment Device Improvement Chemical Laser
RKO	Relativistic Klystron Oscillator
RF	Radio Frequency

S

S&T	Science & Technology
SBIR	Small Business Innovative Research
SBL	Space Based Laser
SEAD	Suppression of Enemy Air Defenses
SHIVA STAR	Free world's most powerful fast capacitor bank
SLBD	Sea Lite Beam Director
SMC	Space & Missile Systems Center
SNL	Sandia National Laboratory
SOI	Space Object Identification
SOR	Starfire Optical Range
SPO	System Program Office
S/V/L	Survivability/Vulnerability/Lethality
SWC	Space Warfare Center

T

TAME	Tilt Anisoplanatism

	Measurement Experiment
TAP	Technology Area Plan
TEO	Technology Executive Officer
TMD	Theater Missile Defense
TPDEW	Technology Panel for Directed Energy Weapons
TPIPT	Technology Planning Integrated Product Team
TW/AR	Threat Warning/Attack Reporting
TIRR	Technology Investment Recommendation Reports

U

USSPC	US Space Command
UWB	Ultra Wideband

W

WL	Wright Laboratory
WSMR	White Sands Missile Range

INDEX